Situational Reservoir Simulation

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Abstract

HEC's ResSim reservoir simulation program can implement reservoir operation schemes for situations with conflicting project purposes or operational measures. Traditional flood control reservoir simulations are generally characterized by tight adherence to a single guide curve, which provides for less than optimum realization of benefits for authorized purposes. Water control managers must adapt idealized operational guidance to individual situations. When successful, this increases benefits for authorized project purposes, including environmental benefits, without compromising project operation.

ResSim can implement this type of operation through multiple guide curves and situational logic. Three examples are presented from the Kanawha Basin: return to normal operation after release of flood storage, variable spring refilling, and buffer operation at seasonal pool.

Introduction

Water control plans embody compromises among competing project purposes. A compromise of this type could take form as tradeoffs between flood control and recreation. When operational measures create conflicts, a project purpose could appear to work against itself. For example, the same generous minimum outflow that benefits the downstream fishery also could produce mud flats that interfere with spawning in the lake area. The crux of the matter is discerning what qualifies as "helpful" and when a particular operational measure is helpful. This paper will show that situational reservoir simulation can contribute to evaluation of operational measures that provide an incremental increase in project benefits, especially as relating to the environment. References to capabilities and features of HEC ResSim apply to Version 1.1.06, which was used in the simulations discussed herein.

Situational Arbitration

Arbitration is used to settle disputes between people. When project purposes or operational measures are in conflict, water control managers must choose one purpose or operational measure over another in much the same way as an arbitrator judges disputes. Judgment becomes situational when the judgment changes as the situation surrounding the judgment changes. Situational arbitration, as used in this paper, refers to selecting appropriate operational measures where project purposes or standard operational measures conflict, and the conflict occurs within a complex and dynamic situation. The concept is as old as reservoir regulation.

A decision to make releases during downstream flooding to minimize future spillway flow involves situational arbitration, since a highly dynamic situation will ultimately determine the effectiveness of operational decisions made under the uncertainty of the moment. A gate closure for downstream flood control, even if the closure produces recreational damages in the lake area, is not situational. Flood control always takes priority over recreation, regardless of the situation.

Project characteristics are thought of normatively and statistically during the formulation and design stages of a flood control reservoir. One notable example of this is the computation of the project PMF inflow hydrograph, which is derived statistically. Only after design alternatives are available for detailed analysis are proscriptive tools set aside in favor of descriptive models. To continue the previous example, this is the proper time to weigh spillway capacity against reservoir volume. Project features interact with each other, and with the environment. Since this interaction varies with the situation, a modeling effort that implements situational arbitration must be situationally aware, and must be sensitive to the interactions.

The assumption of traditional flood control reservoir rule curve operation is implicit in the program logic of ResSim. However, this logic can be circumvented. Situational arbitration schemes can be easily implemented by exploiting ResSim's capability for multiple reservoir operating zones, each with its own set of flexible operating rules. A rule making outflow a function of inflow has been particularly useful. Rules can simultaneously vary seasonally and with respect to a chosen parameter. This tool allows evaluation of situational arbitration scenarios by providing measurable indicators of benefits and liabilities. For example, flexible operating plans could balance the risk of excess storage when refilling early against the risk of not reaching seasonal level by the scheduled date. As another example, operating plans could include variable release rates during refilling, dependent on actual refilling progress as well as past, present, or anticipated runoff. Situational reservoir simulation over the period of record will reveal if, or how much, the proposed operating plan will deliver the intended results.

Slow Down Zones

The Huntington District implemented a multiple guide curve operating scheme during the early development of the Levisa Fork (Kentucky) Basin CWMS ResSim model. After a lake rise, ResSim dropped the lake level at maximum permissible rates until abruptly halting it at the designated normal pool level. In reality, damtenders would reduce the rate of lake recession over several days in a gradual transition to a stable lake level. Mr. James M. Schray, Hydraulic Engineer in CELRH-EC-WM, devised a series of graduated zones with progressively reduced rates of lake recession. Simulations of lake levels falling through these zones, called Slow Down Zones, approximated observed lake recessions.

In this example, damtenders would slow the rate of lake recession for several valid reasons. First, inaccuracies in the outflow rating at high flow rates led to uncertainty in computation of lake inflow, which complicated the scheduling of gate changes. Second, reservoir managers were under pressure to reduce the use of overtime. It was much easier to schedule gate changes over two days than to try to fit them within one duty day. Third, a rapidly falling lake level burdened work crews cleaning roads and parking lots of mud and debris by increasing the difficulty of access to wash water. Last, large, rapid declines in tailwater elevations could increase the probability of bank failure in reaches with poor river bank stability.

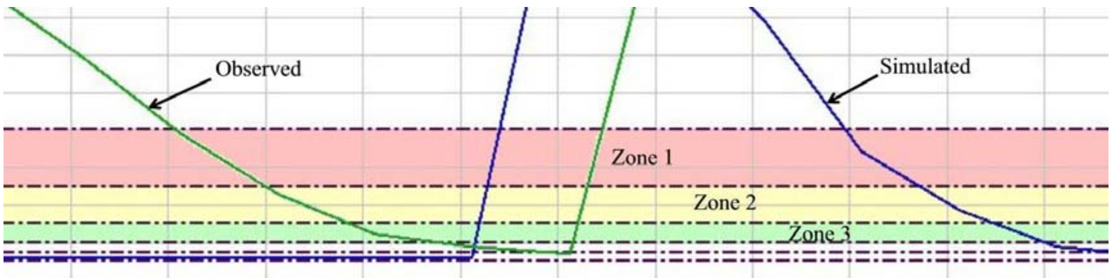

Figure 1

Figure 1 shows an experimental time versus lake level calibration run of Slow Down Zones at Sutton Lake, near Sutton, West Virginia. Each horizontal division represents one day. The basic conflict of flood control with other project purposes is mitigated by the timing of the operation. The slowing down of the drawdown occurs in clear weather with no perceptible imminent flood threat. This operation also generates the economic benefit of decreased labor, the political benefit of clean facilities, and the environmental benefit of decreased erosion. A realtime model not sensitive to the realities of this situation would lose credibility with the public because it would produce predictions of rapid lake recession with no transition to stable pool.

Variable Refilling Rates

The original Water Control Plan of Sutton Lake provided for a variable refilling rate. The outflow during refill varied from 200 c.f.s. in a wet year to 75 c.f.s. in a dry year, depending on day of the month and the lake elevation. Figure 2 shows the refilling zones in terms of time versus lake level. Each horizontal division represents two weeks. The outflow is reduced to 75 c.f.s. if the lake level cannot be maintained in the 120 c.f.s. refilling zone or higher. This Water Control Plan arbitrates between the environmental needs of the downstream fishery and the need to fill the lake for the summer recreation season and for low flow augmentation. In this respect, the Water Control Plan is situationally aware. This refilling plan was incorporated into a ResSim model by establishing multiple guide curves and defining seasonal refilling rules. A period of record situational reservoir simulation would quantify the benefits of this plan over a more traditional refilling with a fixed discharge.

Figure 2

Both Sutton Lake and nearby Summersville Lake are operated for low flow augmentation. Summersville Lake is the fourth-largest water quality reservoir in the Ohio River Basin. Spring refilling is critical to this project purpose. Because of the large volume of water quality storage, spring refilling at Summersville Lake can be difficult in dry years. Flood events in late winter sometimes result in significant lake storage just prior to refilling. The concept of variable refilling rates can be expanded to include refilling earlier in the season. If the lake is storing water in late winter, instead of drawing the lake level down to winter level and then starting to refill, the District usually deviates from the water control plan and temporarily holds a portion of the storage. Although the most visible benefit is the assurance of prompt refilling, this type of operation also has the incidental environmental benefits of avoiding large excursions in both lake levels and tailwater discharge.

Figure 3 shows a rough approximation of current District practice at Summersville Lake. The Slow Down Zones have been redefined to stretch significantly above normal pool levels just prior to refilling. Lower lake levels, near winter pool, are stabilized about two weeks before start of refill. Higher lake levels are not stabilized until closer to the start of refill. Outflow in the Slow Down Zones is set to be a function of inflow, and the function varies with time. Lake recession rates just prior to refill are about half of their value at other times. In this way, lake recession can be varied by time and by elevation, which makes the simulation situationally aware. The data in Figure 3, from a dry year, show a gain in simulated lake level about equivalent to one-sixth of the elevation difference between seasonal levels. The same simulation, not illustrated, shows that summer level would have been reached several weeks earlier if the lake rise in late winter would have been stored.

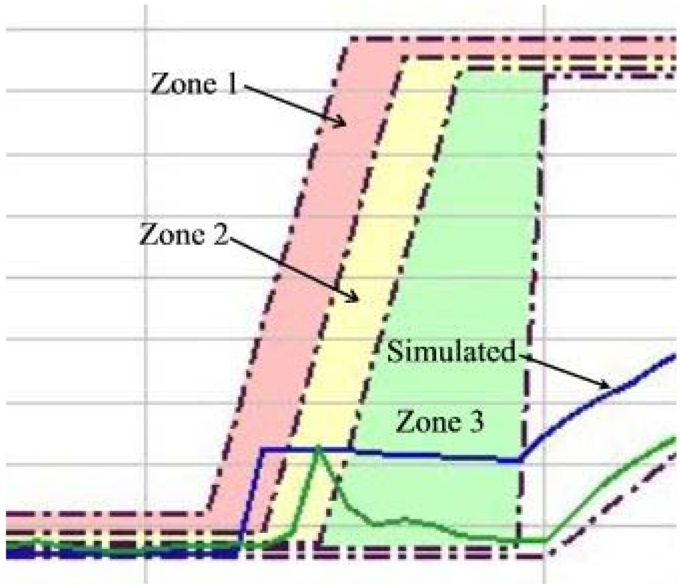

Figure 3

Buffer Operation

The West Virginia Department of Natural Resources requested the Huntington District to provide a 200 c.f.s. minimum outflow at Summersville Lake for the downstream fishery. However, the project is authorized only a 100 c.f.s. minimum outflow. Any release above this level was thought to have the potential to cause negative impacts to lake recreation. As a compromise, the District operates Summersville Lake with a half-foot buffer above summer pool. The minimum release is 200 c.f.s. when the lake level is within this buffer, and 100 c.f.s. if the lake falls below the buffer.

A period of record simulation of this type of buffer operation at Summersville Lake showed that the buffer was not needed as much as was originally thought. There were relatively few days in 2002 when Summersville Lake would have used the buffer operation to provide the 200 c.f.s. release. This is the opposite of the situation at Paintsville Lake, in the Levisa Fork Basin. In the summer of 2002, Paintsville Lake, which more than doubles the minimum release while the lake level is in the buffer, was in buffer operation for almost all of the summer.

A preliminary review of the period of record simulation data showed that most of the time when the lake level is above summer level, the inflow is usually above 200 c.f.s. Therefore, without a buffer, the release would also be above 200 c.f.s. When the inflow nears 100 c.f.s., however, downstream flows also drop and the project begins low flow augmentation. Buffer operation could have raised the outflow a maximum of 100 c.f.s., but low flow augmentation raised it many times this amount. The maximum augmentation flow at Summersville Lake is 1000 c.f.s.

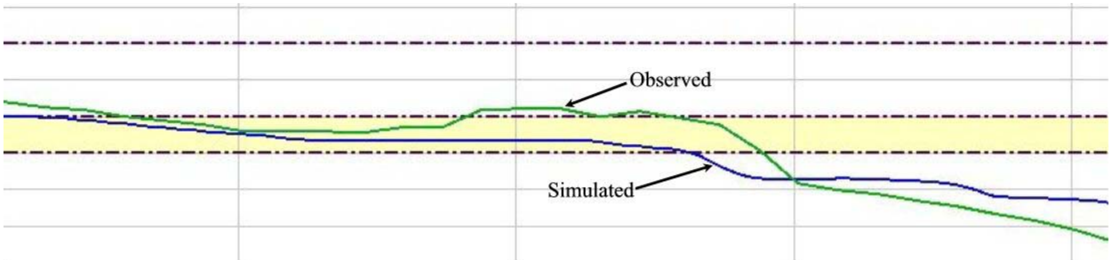

Figure 4

Figure 4, using data from Summersville Lake in July 1993, shows an instance where the inflow slowly recessed below 200 c.f.s. Each horizontal division in the figure represents one week. The project was in buffer operation for about one week, as evidenced by the slight recession in lake level. Because the rule set for the buffer zone did not accurately model the water control plan, the simulated and observed lake levels then began to deviate. The simulated lake level stabilized in the buffer zone, while the observed lake level rose slightly as inflow increased. Buffer zone operation then caused another slight recession in lake level for two days, followed by a short period of low flow augmentation which lowered both the simulated and observed lake levels below the buffer.

The situational arbitration here was between lake recreation and fish and wildlife enhancement in the tailwater area. Minor changes in lake operation produced some benefit to tailwater fishing. The resulting buffer operation at Summersville Lake has not caused perceptible impacts to lake recreation, especially compared with the sometimes drastic effects of low flow augmentation. Low flow augmentation is second in priority among project purposes. Should a prolonged dry period occur that does not require low flow augmentation, operation of the buffer zone could perceptibly benefit the tailwater fishery. In this particular case, the major benefit was not the minor additional flow from time to time for the tailwater fishery, but the goodwill generated by the Corps of Engineers with its willingness to implement minor changes in operational measures to benefit fisheries.

Conclusions

Situational reservoir simulation is useful to measure benefits and liabilities of changes in operational measures to mitigate conflict. It is also useful in implementing realistic realtime forecast models. The additional work of entering multiple guide curves and formulating additional rules of operation for their employment is repaid by the increased utility of the resulting model when the traditional flood control logic implicit in ResSim is circumvented. However, the only way to completely circumvent this logic is to turn off the zone boundary logic, which is not documented in current instructions. Turning off the zone boundary logic complicates regulation of a stable pool, and may not be appropriate in some cases. In other cases, turning off the zone boundary logic may be useful as a diagnostic measure in complex models.